Outcome of a comprehensive follow-up program to enhance maturation of autogenous arteriovenous hemodialysis access

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Objective: **To examine the outcome of a comprehensive follow-up program for autogenous arteriovenous hemodialysis access (AVF) when performed by the hemodialysis access surgeon.**

Methods: **Patients with first time AVFs between 2000 and 2005 underwent history and physical examination between the third and sixth postoperative weeks, followed by repeat examination every 6 to 8 weeks until maturation. Primary outcomes included maturation assessment and interventions required prior to maturation. Maturation was defined as 4 consecutive weeks of sustainable AVF hemodialysis access.**

Results: **One hundred thirteen patients had 113 AVFs. Mean age was 64 years (range: 26-94) and 52% were male. AVFs included 8 (7%) radiocephalic, 90 (80%) brachiocephalic, and 15 (13%) basilic vein transposition. Overall, the maturation rate was 72% (failure rate of 28%). Excluding deaths and transplants prior to maturation, the maturation rate was 82% (failure rate 18%). Eighty-three (73%) patients had no intervention prior to maturation and 30 (27%) required intervention. There was no significant difference in failure rate between AVFs not requiring an intervention (13 of 83, 15%) and those requiring intervention (5 of 30, 16%). For AVFs requiring intervention, 23 (61%) patients had an endovascular intervention and 15 (39%) an operative intervention. One intervention was performed in 64%, two in 24%, and three in 12%. Ninety-three percent of AVFs having an endovascular intervention matured compared with 60% having operative intervention ($P = .10$). AVFs requiring intervention had a maturation time (mean: 35 weeks, range: 10-54) that was significantly longer ($P = .003$) than those without (mean 11 weeks, range: 6-35).**

Conclusions: **With a surgeon directed comprehensive follow-up program to assess AVF maturation, a large proportion (30 of 43, 69%) of AVFs with a problem were detected. Of those identified, most (25 of 30, 83%) could be salvaged to maturation with intervention. The Kidney and Dialysis Outcome Quality Initiative (K/DOQI) should consider incorporating a comprehensive follow-up program into its guidelines. (J Vasc Surg 2007;45:981-5.)**

The Kidney Disease Outcome Quality Initiative (K/DOQI) represents a comprehensive consensus statement using evidence based methods to provide guidelines to optimize care of patients with chronic and end-stage renal disease (ESRD). First published in 1997 and revised in 2001, K/DOQI recommends that autogenous arteriovenous hemodialysis access (AVF) make up at least 50% of all new permanent hemodialysis access operations.[1,2] Of the 38 clinical practice guidelines for vascular access, guideline 9 addresses the topic of optimizing AVF maturation. Specific recommendations are made regarding optimal diameter and time for cannulation; direct methods to enhance maturation such as hand exercises and obliteration of side branches; and resting the AVF after needle infiltration. There are no recommendations concerning optimal routine follow-up after AVF creation to examine for specific signs of maturation failure.

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The mandate of K/DOQI and other programs such as Fistula First have had success in increasing the numbers of AVFs performed in the United States.[3-6] Nevertheless, failure rates due to lack of maturation continue to be a major obstacle with reports ranging from 25% to 43%. Herein, the outcome of a comprehensive follow-up and intervention program specifically performed by the surgeon following AVF creation is examined.

METHODS

The operative and endovascular procedure database (PATS, Inc. Seattle, Wash) prospectively maintained by the Division of Vascular Surgery at Southern Illinois University was queried for all first time AVFs in patients already on hemodialysis from July 2000 to June 2005 performed by the primary author (R.B.M.). Following patient identification, a retrospective review was conducted. Patients with AVF placed prior to needing hemodialysis were not included in the study. AVF was defined as radiocephalic, brachiocephalic, and basilic vein transposition. All basilic vein transpositions were one stage operations. Charts were retrospectively reviewed for basic demographic information, risk factors, AVF interventions prior to maturation, and maturation time. Maturation of AVF was defined as sustainable hemodialysis access ≥4 consecutive weeks with two needle access and acceptable flow rates (400-600 ml/min).

Preoperative evaluation of patients being considered for permanent hemodialysis access was performed in the outpatient vascular surgery clinic. In determining whether permanent hemodialysis access could be performed in the arm, evaluation included history and physical examination and selected preoperative vascular laboratory studies such as finger plethysmography in patients with hand neuropathy or absent wrist pulses and duplex examination of jugular/subclavian veins for suspicion of occlusion. All patients underwent preoperative arm vein duplex mapping without tourniquet the same day of surgery. Scanning protocol included determining cephalic and basilic vein diameter as well as vein continuity. The largest continuous arm vein was utilized for creation of an AVF, generally regardless of handedness. An arteriovenous graft was placed if the majority of the cephalic or basilic vein lengths were less than 2.5 mm in diameter. Similarly, an arteriovenous graft was placed in morbidly obese patients with only an adequate basilic vein.

All patients undergoing an AVF were followed in the outpatient vascular surgery clinic. The first postoperative visit was between 3 and 6 weeks for examination, suture removal, and patient education. Follow-up ensued every 6 to 8 weeks until the patient was on dialysis using two needles with adequate flow (400-600 ml/min) for 1 month. At each interval of follow-up, the patients underwent directed physical examination for signs of impending thrombosis or lack of maturation. Such signs included the development of a hammer pulse in the proximal AVF, minimal thrill with low flow suspected, minimal increase in vein dilatation, increasing number of branches visualized, increasing arm edema, barely audible or highly pitched bruit, problems with needle cannulation due to AVF depth, or physical signs of suspected stenosis after careful palpation of the entire length of the AVF. Most often, signs of maturation failure were combined such as proximal AVF hammer pulse and palpable distal AVF thickening or minimal AVF distention with barely audible bruit. Duplex examination was selectively used after these physical findings to assure patency. Digital subtraction angiography was performed by the primary author (R.B.M.) in a cardiovascular laboratory with a 15-inch image intensifier if any of these physical signs were detected. Technique generally included antegrade cannulation near the arterial anastomosis, complete peripheral and central venous imaging, and arterial anastomosis evaluation with mid-fistula compression. Based on these results, endovascular and/or subsequent operative procedures were performed if felt to be advantageous to prevent failure and improve maturation. Endovascular interventions included percutaneous transluminal angioplasty for stenoses $\geq$50%. Flextome cutting balloons (Boston Scientific, Boston, Mass) were used routinely. Short occlusions ($<$5 cm) were attempted to be recanalized percutaneously. Procedures necessitating operative intervention included such procedures as branch ligation, revision with arm vein interposition, vein patch angioplasty, and AVF superficialization.

Following any intervention, subsequent follow-up would continue every 6 to 8 weeks. Maturation was determined using physical examination by the vascular surgeon. Criteria used to determine maturation included ease of palpation, quality of thrill, usable length, and accommodating diameter. Upon concluding that these criteria were met by physical examination, sequential needle transition was begun. Generally, this sequence began with the arterial needle (from the patient to the dialysis machine) and utilization of venous flow through the tunneled dialysis catheter for 2 to 3 weeks followed by two needles for 2 to 3 weeks. Patients were then seen in the vascular clinic for removal of tunneled dialysis catheter or evaluated if problems were occurring with needle transition. Depending on the problem during needle transition, the AVF was either rested or an angiogram was performed. AVFs that thrombosed during follow-up were abandoned and considered a failure to mature.

Standard descriptive statistics are used for the data. Statistical comparisons used t-test, chi square, and multivariate analysis. A *P*-value of $\leq$.05 was considered significant.

RESULTS

One hundred thirteen patients had 113 AVFs during the 5-year period. During the same period, 74 arteriovenous grafts were performed (61% first time AVF rate). Mean age of the cohort was 64 years (range: 26-94) and 58% were male. Eighty percent of patients were Caucasian, 19% African-American, and 1% other. Risk factors and comorbidities included 38 (33.6%) patients with a tobacco history, 65 (57.5%) had diabetes mellitus, 92 (81.4%) had hypertension, 50 (44.2%) had coronary artery disease, and 24 (21.2%) had peripheral arterial disease. Upper extremity venous duplex mapping was performed in 109 (96.4%) of patients. Distribution of AVFs included 8 (7%) radiocephalic, 90 (80%) brachiocephalic, and 15 (13%) basilic vein transposition.

There were 83 (73%) patients not requiring intervention and 30 (27%) requiring intervention prior to maturation. Table I shows comparisons of demographics, risk factors, and comorbidities between the two groups. Table II shows the distribution of types of AVFs for those who did and did not require intervention during follow-up. Patients with AVFs not requiring intervention were significantly more likely to be older, Caucasian, and have hypertension. Patients with AVFs requiring intervention were significantly more likely to be African-American. Multivariate analysis revealed no significant demographic associations. Interventions were not observed to be more necessary in any type of AVF.

During the maturation process, there were nine deaths and four transplants, leaving 100 patients requiring maturation. No deaths were due to complications secondary to a tunneled dialysis catheter. In patients not requiring intervention, there were eight deaths and one transplant while in those requiring intervention there was one death and three transplants. Overall, including

Table I. Comparisons of demographics, risk factors, and comorbidities between group I (nonintervention) and group II (intervention)

	Group I n = 83 (%)	*Group II n = 30 (%)*	*P value*
Age	66 (mean)	60 (mean)	.02
Male	42 (51)	17 (56)	.72
White	73 (88)	19 (64)	.007
African-American	10 (12)	10 (32)	.01
Smoker	29 (35)	10 (32)	.99
Diabetes	49 (59)	16 (52)	.74
HTN	72 (87)	20 (68)	.03
CAD	36 (43)	14 (48)	.92
PAD	17 (20)	6 (20)	1

Table II. Distribution of autogenous arteriovenous hemodialysis access (AVFs) procedures for patients not requiring intervention vs those that did require intervention prior to maturation (No specific differences were observed.)

AVFs with:	*No intervention (n = 83)*	*Intervention (n = 30)*
Radiocephalic	7 (8%)	1 (3%)
Brachiocephalic	64 (77%)	26 (87%)
Basilic vein transposition	12 (14%)	3 (10%)

patients that died and had transplants, the maturation rate was 72% (failure rate of 28%). When patients that died or had transplants were excluded, the maturation rate was 82% (failure rate 18%). There was no significant difference in failure rate between patients not requiring intervention (13 of 83, 15%) and those requiring intervention (5 of 30, 16%). None of the patients in the entire cohort who died or had a renal transplant during the maturation process thrombosed their AVF. Alternatively stated, patients who died or went on to transplant during the maturation process were noted to have a patent AVF at last follow-up. No further follow-up was performed on patients having transplant.

If the assumption that all AVFs in patients requiring intervention would have failed if no interventions were pursued, then the total failure rate would have been 38% (nonintervention group failures [n = 13] + assumption [n = 30] = 43). If patients who died or had transplant are excluded, the failure rate increases to 43%. These percentages were each significantly higher ($P < .001$) when compared with the overall AVF failure rate from the comprehensive follow-up program (16% - entire cohort, 18% - excluding deaths and transplants). If the assumption is made that all failed group I AVFs (n = 13) had an undetected stenosis and those that matured were without a stenosis (n = 70), then our routine follow-up with physical examination yielded a sensitivity of 70%, a specificity of 100% and an accuracy of 88%.

Of the 30 patients requiring intervention, 23 (61%) had an endovascular intervention and 15 (39%) had an operative intervention. There was an average of 1.5 interventions per patient with one intervention performed in 64%, two in 24%, and three in 12%. All endovascular interventions consisted of percutaneous transluminal angioplasty. Operative interventions consisted of 12 requiring vein interposition or patch, one requiring superficialization, and two requiring branch ligation. There were no differences in distribution of interventions between AVF types. Ninety-one percent of patients having an endovascular intervention resulted in AVF maturation whereas 60% having operative intervention resulted in maturation ($P = .10$). For those patients needing maturation (excluding transplants prior to maturation and deaths), patients requiring intervention (mean: 35 weeks, range: 10-54) took significantly longer ($P = .003$) than those not requiring intervention (mean 11 weeks, range: 6-35).

DISCUSSION

Routine postoperative physical examination at regular intervals of newly placed AVFs as assessed by the operative surgeon led to the detection of a significant number with problems. All 30 (27%) patients that had angiography after an abnormality was discovered on physical exam had a procedure to increase the likelihood of maturation. Of those, 25 went on to mature with use of two needles for at least 30 days. Findings on physical exam that could indicate a problem include: minimal increase in vein size in a person with easily visualized veins; little or no thrill; barely audible or high pitched bruit; the presence of a hammer pulse; increasing predominance of branches emanating from the AVF; increasing arm edema; signs of stenosis after careful palpation of the AVF; problems with needle cannulation due to AVF depth.

Although the reliability of physical examination can be variable, this fact has to be weighed against the variability that would occur given the predominant standard of one or no postoperative visits by the same hemodialysis access surgeon following AVF creation. Moreover, regular follow-up in hemodialysis units is subject to changes in nurse staffing. Nevertheless, one may assume that given poor maturation in a defined number of patients, nephrologists and/or dialysis nurses would obtain an angiogram to assess for problems in a proportion of our cohort. The difference with more rigorous follow-up is to heighten awareness and standardize the physical exam by the operating surgeon for all patients to prevent thrombosis in those threatened AVFs. Few AVFs can be salvaged after thrombosis prior to maturation. It is the authors' belief that AVFs with a hammer pulse, minimal thrill, and high pitched bruit are at most risk of thrombosis prior to maturation because this constellation of findings is typically not regarded by most physicians and allied health professionals involved with hemodialysis as worrisome.

Consistent follow-up prior to maturation remains the key to detection. In our study, this follow-up was provided

at regular intervals by the same vascular surgeon. Such follow-up, while waiting for maturation, becomes more difficult in a busy dialysis unit with many allied health professionals and other physicians (nephrologists, primary care physicians, radiologists, and consultants) attending to the patient. Additionally, surgeons who routinely perform large numbers of AVFs are more likely to be better skilled in assessing for lack of maturation from careful and meticulous physical examination. These skills are transferable with appropriate education and volume.

It must be emphasized that the skill of physical exam by the vascular surgeon is far from perfect. There were still 13 (12%) patients whereby physical examination did not detect problems and the fistula did not reach maturation. Our vascular laboratory does not perform routine duplex surveillance of AVFs and henceforth, has not performed a rigorous receiver-operator curve to determine the accuracy in detecting greater than 50% stenoses. The results of duplex for AVF and AV-graft surveillance have been mixed. In a recent prospective randomized trial of 186 patients with AV-grafts by Robbin et al, duplex surveillance was no better than clinical monitoring to enhance AV-graft patency.[7] Although angioplasty was performed significantly more often in those AV-grafts having duplex surveillance, median time to permanent graft failure did not differ between the two groups (38 vs 37 months, $P = .93$). Similarly, Lumsden et al. determined that AV-graft duplex surveillance did not lead to improved patency.[8] Little information is published regarding duplex surveillance in AVFs. From a small study in 1989, peak systolic Doppler frequency was noted to have a sensitivity of 79%, a specificity of 84%, and an accuracy of 81% in detecting greater than 50% stenosis in 36 Brescia-Cimino AVFs.[9] There are no clinical reports documenting duplex surveillance in AVFs that in the process of maturing. These duplex findings may be different from duplex surveillance in the mature AVF.

Given the reported range of AVF maturation failure (25% to 43%), a more rigorous follow-up program may be one area to prevent premature failure due to undetected stenoses that could have been remedied by percutaneous or operative intervention prior to maturation. We recommend that patients with AVFs return for a first postoperative visit to the surgeon's office in 3 to 6 weeks, and then, every 6 to 8 weeks thereafter to assess progression of fistula maturation. The key issue to detecting problems by physical exam is understanding the physical signs for potential problems and consistency in having one person dedicated to reexamining the patient. Theoretically, this could be implemented in a dialysis unit by a trained allied health professional as well. Certainly, even with an overall failure rate of 18% in this study (less than many other published reports), routine surveillance by angiography prior to presumed maturation or needle access for all AVFs may be the best way currently to assess for problems that could be developing after 30 days. With technical errors and poor patient/vein selection yielding AVF failure in a majority of patients prior to 30 days, a case for AVF surveillance using angiography prior to cannulation may be warranted.

The lack of a control population in this study represents a weakness. Nevertheless, the discovery of 30 AVFs needing intervention prior to maturation speaks to the power of a comprehensive follow-up program. K/DOQI recommends a 3- to 4-month period to time for AVFs to mature prior to cannulation.[2] This interval may be misinterpreted by nephrologists and surgeons that little assessment should be done prior to that time. Our study has shown that 58% of patients with a presumed lesion were identified and treated with intervention. Most patients having intervention (83%) matured their AVF. Information from this study leads the authors to believe that lack of comprehensive follow-up to assess fistula maturation will lead to increased AVF failure and potentially even longer dependency on tunneled dialysis catheters. Although those patients with intervention had prolonged time to maturation in this study, this time could be further worsened if AVF problems are not identified sooner. Prospective trials are needed to assess fistula maturation with different examination and imaging techniques. Until then, K/DOQI should adopt strict guidelines for a comprehensive follow-up program for AVFs prior to maturation. Further consideration should be made to recommend routine angiography prior to cannulation of AVFs.

AUTHOR CONTRIBUTIONS

Conception and design: RM, RP
Analysis and interpretation: RM, RP, DR, KH
Data collection: RP
Writing the article: RM
Critical revision of the article: RM
Final approval of the article: RM, RP, DR, KH
Statistical analysis: RM
Obtained funding: RM
Overall responsibility: RM

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